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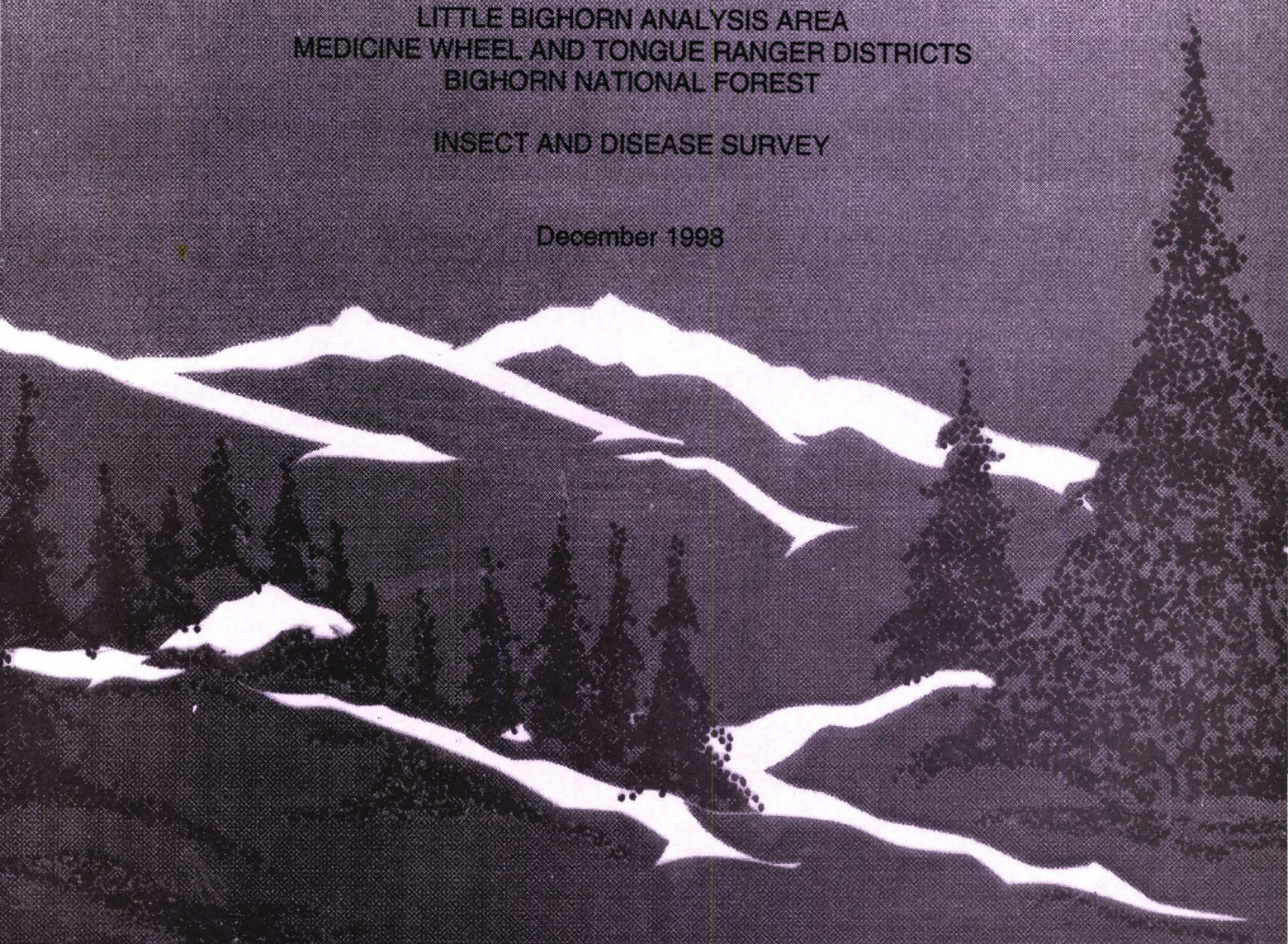
Forest Health Management

BIOLOGICAL EVALUATION
R2 - 99 - 03

LITTLE BIGHORN ANALYSIS AREA
MEDICINE WHEEL AND TONGUE RANGER DISTRICTS
BIGHORN NATIONAL FOREST

INSECT AND DISEASE SURVEY

December 1998



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ABSTRACT

Bighorn National Forest managers are writing an environmental assessment for use of prescribed fire to protect and enhance fire dependent forest conditions in an 102,705 acre area delineated as the Little Bighorn Analysis Area. Of the 72,244 forested acres in the analysis area, 45% have a spruce-fir cover type. The remaining acres are covered by 22% Douglas-fir, 19% lodgepole pine, 12% limber pine, 1% ponderosa pine, and 1% aspen. Prominent insect and disease activities may impact forest management objectives for the area and are discussed in detail. Forest Health Management surveyed 12.5 miles of chain-wide survey transect lines throughout the area's forested stands to assess the current insect and disease damages in the Little Bighorn Analysis Area. Dying or recently dead trees along the lines were examined for beetle or/and root disease activity. Variable-radius plots were used every 10 chains to rate dwarf mistletoe and rust diseases in the pines. Most of the damage in the spruce-fir forest type was caused by western balsam bark beetle and spruce beetle. Activity levels for the subalpine fir were 2.3 trees per acre killed; this is considered near outbreak level. Mountain pine beetle activity was at an endemic level with less than 1 tree killed per acre. Comandra blister rust and dwarf mistletoe diseases have infected 40% of the lodgepole pine in the area. Sixteen percent of all the lodgepole pines surveyed have both diseases. Twelve percent have only comandra blister rust disease and another 12% were infected with dwarf mistletoe disease only. The comandra blister rust incidence is high; an average severity rating for these trees indicates that most are topkilled and dying. Dwarf mistletoe incidence has dropped from 36.5% reported in 1986 to 30% in this survey. This may be due to the large number of spruce-fir stands in the area and lack of continuous lodgepole pine forest needed for spread. Armillaria root disease was found on one site in the Leaky Mountain area of Boyd Ridge. Low infection levels of white pine blister rust have also been found on the limber pine of the area. Recommendations are to use prescribed fires, thinnings, and some overstory removal depending on forest cover types. This will promote more pine and aspen regeneration and help protect the sites from harmful insect and disease outbreaks.

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INTRODUCTION AND MANAGEMENT OBJECTIVES

Bighorn National Forest managers are developing an environmental impact statement for proposed vegetation management plans for a 102,705 acre area delineated as the Little Bighorn Analysis Area. The management that is proposed is the use of prescribed fire to protect and enhance the fire dependent forest conditions that occur within this area. Within this broad objective, other desired outcomes include enhancing livestock forage and wildlife habitat and reducing hazardous fuel loads. This management should promote vegetation diversity, reduce heavy fuel loads, minimize insect and disease populations, and renew plant health and vigor. Both low and high intensity fires will be used to accomplish these objectives.

The Little Bighorn Analysis Area is named for the Little Bighorn River in north-central Wyoming and contains 72,244 acres of forested lands. Approximately 45% of the forested lands in this area are mostly a spruce-fir cover type . Engelmann spruce (*Picea engelmannii*) and sub-alpine fir (*Abies lasiocarpa*) comprise these spruce-fir stands. Douglas-fir (*Pseudotsuga menziesii)* is a dominant forest tree of 22% of these forest acres. Pines cover 31% of the forested lands of this area with 19% lodgepole pine (*Pinus contorta*), 12% limber pine (*Pinus flexilis*), and 1% ponderosa pine (*Pinus ponderosa*). Each of these forest types occur as both pure stands or mixed with other conifer species. Finally, 1% of the forested area is covered with quaking aspen (*Populus tremuloides*).

Wildfires were common disturbances to this area. Stand-replacing wildfires used to burn the lodgepole pine stands approximately every 120 years. Spruce-fir stands had longer fire intervals of 300 - 700 years that were also high-intensity wildfires. Fire has been the main decomposer and recycler of nutrients for the area's vegetation. Fire suppression practices over the last 100 years has allowed the area to accumulate heavy fuel loads. Current conditions are such that large, stand replacing wildfires are likely to occur if nothing is done.

Disease and insect activities may impact forest management objectives for the Little Bighorn Analysis Area. Prominent insect and disease problems of the spruce-fir and Douglas-fir cover types are spruce beetle (*Dendroctonus rufipennis)*, Douglas-fir beetle (*Dendroctonus pseudotsugae)*, and western spruce budworm (*Choristoneura occidentalis).* Another forest health problem, fir decline, is currently being investigated in the Central Rocky Mountains and in this area. It appears to be caused by western balsam bark beetle *(Dryocoetes confusus)* activity and root diseases.

The pine cover types are susceptible to mountain pine beetle (*Dendroctonus ponderosae)* and several diseases. Comandra blister rust (*Cronartium comandrae)* and dwarf mistletoe (*Arceuthobium americanum)* diseases occur at high incidence levels in lodgepole pine stands throughout Wyoming. Outbreaks of a needlecast disease (*Lophodermella* spp.*)* on lodgepole pine have also occurred on the Bighorn National Forest. The other major pine of the analysis area, limber pine, has been noticed to be declining. This decline may be caused by one or several factors such as mountain pine beetle, white pine blister rust (*Cronartium ribicola)*, dwarf mistletoe *(Arceuthobium cyanocarpum)*, and a needlecast disease (*Dothistroma septospora).*

Each of these insects, diseases, and types of decline may impact management objectives for the Little Bighorn Analysis Area. Spruce and Douglas-fir beetle, western spruce budworm and fir decline will be discussed in detail as to their ecology and management. Mountain Pine beetle and the pine diseases of rusts, dwarf mistletoes, and needlecast diseases will also be discussed.

ECOLOGY & MANAGEMENT OF THE MAJOR FOREST INSECTS AND DISEASES

Spruce Beetle

The most prominent threat to spruce is the spruce beetle. The spruce beetle is a native bark beetle that occurs throughout the range of spruce in North America. The beetle is found at endemic levels in downed trees and large pieces of slash. Epidemic populations most often occur after large disturbances, such as windthrows, affect a large volume of host material. Once populations reach an epidemic stage, all sizes of standing green spruce can be attacked except for reproduction. While all sizes can be attacked, it is most often focused on the larger trees within a stand. Much like mountain pine beetle, it can cause drastic changes in stand structure and composition.

The spruce beetle usually requires two years to complete a generation, in high elevations it can take three years. Adults fly, attack host trees, and lay their eggs in June and July. Larvae develop under the bark and remain there to overwinter. Larval development continues the following spring and summer, with new adults emerging in August. These adults then hibernate beneath the bark until the following June and July.

Spruce stands that are most susceptible to spruce beetle outbreaks generally have the following characteristics (Schmid and Frye 1976):

1. Are located in creek bottoms.
2. Have large diameter host trees.
3. Have high basal areas.
4. Have a large proportion of spruce in the canopy.

Spruce beetle is a concern that should be noted in stands that have large mature and overmature trees. Windthrow events in or near these stands can lead to mortality of standing green trees (Schmid and Hinds 1974). Spruce beetle populations have been detected in the Medicine Wheel area in the 1970's and 1980's and were associated with blowdown trees.

Spruce beetle, unlike mountain pine beetle, is attracted, and often builds up in damaged trees. Frequently this is in windthrown/blowdown trees, however, fire scorched trees also are susceptible. For example, Rasmussen et al. (1996) found an increased number of spruce beetle in trees that were scorched up to a certain level of damage. Once scorching

exceeded 60% of the basal circumference girdled, trees were no longer as suitable for spruce beetle infestation. This is something to be considered when using prescribed fire. Many of the larger spruce may have bark thick enough to survive lighter prescribed burns, however, if they are scorched somewhat, they can be more susceptible to spruce beetle. Stands that contain a large number of larger, partially scorched spruce, could be centers for spruce beetle buildup and epidemics.

Douglas-fir Beetle

The Douglas-fir beetle is the most damaging bark beetle found in Douglas-fir. It occurs in Douglas-fir throughout its range in the west. The Douglas-fir beetle has one generation per year. Adults or larvae overwinter under the bark and in the following summer emerge and attack nearby host trees. The beetle typically kills individual or small pockets of trees, but under the right conditions can reach epidemic levels and kills large pockets of host trees.

Stands that are most susceptible to Douglas-fir beetle outbreaks have the following characteristics (Furniss et al. 1981):

1. Stand density, stands stocked at 80% or more of normal are most susceptible.
2. Stand age, trees 120 years of age and older being the most susceptible.
3. Proportion of Douglas-fir in the canopy.

Douglas-fir beetle is also a concern in areas that have other disturbance events that can leave a large number of damaged host trees available for beetles to build up in, such as windthrow and fire (Furniss 1962, Furniss 1965, Rasmussen et al. 1996). Once populations build up in these damaged trees, infestations can then move into nearby green trees. This is a concern for both natural events and prescribed fires, either of which could damage residual trees enough to start a Douglas-fir beetle epidemic. Heavy Douglas-fir mortality caused by Douglas-fir beetle was observed along Porcupine Creek and other areas west of the Little Bighorn Analysis area in the 1997 aerial survey and in the late 1960's. This mortality was likely associated with blowdown events.

Western Spruce Budworm

The major defoliating insect of concern in this area is the western spruce budworm. The larvae feed on the current year buds and foliage of its host trees, principally Douglas-fir and true firs. Heavy attacks cause complete defoliation after 3 or 4 years, which results in reduced growth, top killing, and tree mortality. There is one generation per year. Eggs are laid in July or August, larvae emerge in about 10 days. The larvae do not feed at this time, but instead spin shelters under bark scales where they spend the winter. In the spring the larvae start by mining old needles, then bore into expanding buds and feed on the new needles.

Stand susceptibility to budworm defoliation depends on a number of factors. Some of these are (Wulf and Cates 1985):

1. Proportion of host in the stand, the higher the proportion of host trees, the higher the susceptibility.
2. Stand density, dense stands are more susceptible than more open stands.
3. Stand structure, multi-storied stands are more susceptible as they generally have host species in the understory that will provide a suitable host for dispersing larvae.

Moderate to severe levels budworm defoliation were documented in the northwest portions of the Bighorns National Forest in the mid-1980's and in 1994.

Fir Decline

Losses of subalpine fir are harder to quantify. At this time, there is widespread "fir decline" taking place throughout the Rocky Mountains of Wyoming and Colorado. Large areas of subalpine fir decline have been observed on the Bighorn National Forest and within the Little Bighorn Analysis area during recent aerial surveys. The exact causes have not been defined. One player in this decline is the western balsam bark beetle. This beetle has been found killing sub-alpine fir in the western states. Lodgepole pine and Engelmann spruce and also have been occasional hosts. The impacts this beetle has as a part of "fir decline" are unknown.

Other possible agents of fir decline are root diseases. This group of diseases can cause mortality, slow tree growth, and make trees more susceptible to other harmful pests such as mountain pine beetle or dwarf mistletoe. They can increase windthrow damage by weakening root systems and will hinder restocking levels by killing regeneration (Morrison 1981; Wargo and Shaw 1985). Very little root disease study has been done on the Bighorn National Forest and Forest Health Management hopes to do more surveys to find these important diseases. Two possible root disease pathogens that may occur in these fir stands of the Little Bighorn Analysis Area are *Armillaria* spp. and Annosus (*Heterobasidion annosum*).

Armillaria occurs on several conifer species and aspen and often acts as a decayer of dead wood such as logging stumps. It spreads primarily through root contacts, but may also have some incidental spread by rhizomorphs or spores. Rhizomorphs are shoestring-like structures of fungal tissue that grow through the soils and infect new roots. This fungus is often called the 'shoe-string' fungus. Armillaria may also produce mushrooms at the base of trees after early winter storms in September and October. These mushrooms release spores to start new infection centers (Morrison 1981).

Annosus root disease is common in fir stands in the Rocky Mountain Region. The fungus is spread by root contacts, root grafts, and by spores. Fungal conks found in stumps and dead trees will release wind-borne spores to infect fresh cut surfaces and wounds (Johnson 1985).

Root disease centers will appear as a circular area with several dead and dying trees, perhaps some trees fallen over at the root collar. Young seedlings and saplings will also be dead, especially if they are growing next to a stump. Surrounding trees will have thin

crowns, off-color foliage, resinous bases and root collars, perhaps a stress cone crop, and declining growth (Shaw and Kile 1991).

Possible controls for root disease are to favor other resistant tree species, usually lodgepole pine in this area. When necessary to cut root disease-infected trees, a 30 - 50 foot buffer around the disease center should also be cut to prevent the disease from spreading through stumps in the stand. If the root disease is *Annosus*, then borax may be applied to fresh cut stumps to make the stump uninhabitable by spores of the fungus.

Mountain Pine Beetle

The most serious insect pest of pine throughout the west is the mountain pine beetle. This is a native beetle that kills all of the pine species (lodgepole, ponderosa, and limber pine) in the Little Bighorn Area. Mountain pine beetle activity has historically been relatively light and scattered; however, outbreaks have been recorded in the late 1960s and mid-1970's in both Little Bighorn River area and the eastern slopes of the Bighorn Mountains. The mountain pine beetle can, however, reach epidemic proportions and kill significant amounts of their hosts. Although beetle behavior is fairly well understood in relation to lodgepole pine stands, the same cannot be said of ponderosa and limber pines. In lodgepole pine the beetle generally attacks large diameter, overstory trees, although once an epidemic starts, smaller trees can also be killed (Amman and Cole 1983). The death of overstory trees influences stand structure and composition, and can lead to stand conversion to other species.

The mountain pine beetle generally completes its life cycle in one year in lodgepole pine, although at higher elevations it can take two years (McGregor and Cole 1985). Adults typically emerge sometime in July or August and attack standing green trees. On successfully attacked trees, adults lay eggs and larvae develop under the bark. Immature larvae overwinter under the bark, then finish feeding in the spring and early summer. The developing larvae feed on the phloem, killing the tree.

Mountain pine beetle populations in lodgepole pine are in a large part dependent on the conditions present in the forest. In lodgepole pine, susceptibility to mountain pine beetle is based on three factors (Amman et al. 1977):

1. Average tree diameter,
2. Average tree age,
3. Location by latitude and elevation.

Beetle behavior in ponderosa pine is not as well understood. The only work that has been done relating forest conditions to beetle susceptibility has been done in the Black Hills of South Dakota and Wyoming. In these areas, beetle susceptibility is based on tree diameter and stand density (Schmid and Mata 1992). Average stand diameters of over 7.0 inches makes for susceptible stands. In stands that are above the minimum diameter, stands that have a basal area of over 120 square feet per acre are considered to be high risk. Stands with a basal area between 80 and 120 are moderate risk and those below 80 basal area

are low risk (Schmid et al. 1994). It will be assumed that these same criteria are applicable to ponderosa pine on the Bighorn National Forest as well.

Little work has been done on mountain pine beetle behavior in limber pine. What is known is that brood production is fairly high in limber pine, indicating that beetles do very well in this species (Cerezke, 1995). It will be assumed that the beetle behaves in much the same way in limber pine as in lodgepole, preferring larger diameter trees.

In both lodgepole and ponderosa pine, the factors that can be managed to reduce a stands susceptibility to beetles are reducing average diameter and age and/or reducing stand density. Treating the stands to reduce susceptibility will provide the most long-term defense against a mountain pine beetle epidemic. In lodgepole pine, thinning is effective at reducing future losses to the mountain pine beetle (Amman et al. 1988, Cole 1989, Gibson 1989, McGregor et al. 1987). Since beetles are attracted to the largest trees initially, removal of large diameter material is also effective at reducing loss during epidemics (Cahill 1978, Cole et al. 1983, McGregor et al 1987). Obviously, clearcutting lodgepole pine stands removes any risk of beetle infestation.

Treatments to reduce mortality in ponderosa pine include thinning stands to lower basal area prior to beetle outbreaks. Beyond this, not much is known as far as what else is effective at reducing loss to the beetle in ponderosa pine. Sanitation harvesting over large areas prior to the 1999 flight period (July - August) may serve to reduce localized beetle spot expansion. However, sanitation harvesting on a small scale does not prevent future bark beetle migration from adjoining areas.

There has been no work done on silvicultural treatments for reducing beetle damage in limber pine. Based on what is known from lodgepole and ponderosa, limber pine stands should be treated to remove the largest diameter trees and reduce stocking levels. Without any real information, these seem to be the safest options for minimizing beetle damage.

Work on how fire and fire scarred trees would effect mountain pine beetle populations has shown that this beetle does not search out and infest fire scarred trees (Rasmussen et al. 1996). In other words, the use of prescribed fire and the resulting fire scarred trees would not be any more susceptible to causing beetle population increases.

Comandra blister rust disease

Comandra blister rust is the one of the most damaging disease agents of lodgepole pine in Wyoming (Mielke 1957). This rust fungus may also infect ponderosa pine in the Little Bighorn Analysis Area. High levels of comandra blister rust in the lodgepole pine may then promote infection to nearby ponderosa pine stands of the area, since ponderosa pine can also be a host of this disease.

Rust fungi frequently occur with dwarf mistletoes but it is unknown if either disease makes the tree more susceptible to infection by the other disease (Schaffer and Hawksworth 1983). Also rust and dwarf mistletoe diseases may predispose the pines to mountain pine

beetle attack. When bark beetle populations build up in disease-stressed trees, then the beetles can attack and kill nearby healthy trees.

The rust produces girdling cankers on stems of pine trees. These cankers cause topkill of the trees and which can significantly alter canopy structure. The canopy opens when trees are topkilled; smaller lodgepole pines and regeneration of later successional species are released (Peterson 1962; Krebill 1967).

Comandra blister rust is a native rust fungus which requires two different hosts to complete its life cycle, bastard toadflax (*Comandra umbellata*) and hard pines such as lodgepole pine. The spores are spread by wind from the comandra plants to infect pine needles and new shoots. The fungus then grows into the branch, creates a canker that kills the branch. These cankers often produce spores that appear as rust-colored blisters; these spores travel back to infect the comandra plant. As the fungus grows in the tree branch, it will advance towards the tree stem. If the fungus forms a girdling canker on the stem then the distal portion of the tree dies causing topkill (Mielke 57).

Growth stops for the topkilled tree unless it can grow a new top (Geils and Jacobi 1993). Sometimes a lower branch beneath the canker assumes terminal dominance and grows a new top. This new top helps the tree to start growing again, yet it appears as a fork or crook which may reduce the timber quality. New tree tops are only effective for a few years. The girdling stem cankers that originally caused topkill continue to advance, regirdle the stems, and cause topkill a second time (Geils and Jacobi 1993). Depending on tree size and site quality, the tree may live several more decades before succumbing to the disease or being killed by another mortality agent.

These spike-top trees have several disadvantages for forest management. Declining topkilled trees continue to use site resources, and prevent healthier, younger trees from vigorous growth. The topkilled stem portion may become a fuel ladder for low intensity fires to climb into the canopy and become wildfires. Tree spike-tops are also unusable for timber and create aesthetically unattractive landscape views.

Younger trees stand a greater chance of infections developing into stem cankers (Johnson 1979). While younger trees have less crown to be exposed to rust spores and had less time of exposure, when a successful spore infection does occur on young tree foliage then this new infection may quickly develop into a girdling branch canker (Geils and Jacobi 1990). A small branch may also be within close proximity to the tree's main stem and so this girdling branch canker may develop into a stem canker. If the tree is small enough, then the stem canker will successfully girdle the stem. Being a small tree, the amount of topkill caused by the girdling stem canker will be more detrimental to the survival of the young tree than the girdling stem canker described above for a large tree (Geils and Jacobi 1990).

Comandra blister rust is widespread in the Western U.S. and occurs in about 25% of Wyoming's lodgepole pine stands (Andrew and Harrison 1959). This disease may have occurred at low levels throughout the 19th century. It appears to have dramatically increased

from 1910 to 1945 due to unusual warm, moist, summer fronts (Krebill 1965). Lodgepole pine stands have increased in tree density and competition due to fire suppression. This has led to a larger food base for the rust fungus with less vigorous trees to tolerate/resist the disease.

Current management for this disease is to reduce the disease incidence in lodgepole pines stands rather than trying to prevent the disease. Control of the comandra plant is not possible. Since the infection levels of the disease are already high in Wyoming and the spores are spread by the wind, most lodgepole pine of the area have a great chance of being infected.

Heavily infected stands ought to be harvested as soon as management permits. Past studies in other forests in Wyoming have found that the trees start becoming topkilled at about eighty to ninety years of age. Trees with multiple cankers, cankers in the lower third of the live crown, or with half of the crown topkilled ought to be removed during selective cuttings (Johnson 1986). Sometimes cankers may be pruned from high-value trees.

If lodgepole pine is to regenerate a harvested site, then the stand should be overstocked since losses will occur due to the rust. Seed trees that remain should be free of the disease to lower incidence on the site and also possibly regenerate trees that have a higher tolerance to the disease (Johnson 1986). If site quality is poor, intensive management should focus on mitigating as much disease damage as possible. There is a strong correlation between site index and percent mortality. As site quality improves, rust-caused mortality decrease (Jacobi et al. 1993).

White Pine Blister Rust

White pine blister rust (*Cronartium ribicola*) infects only limber pine trees on the Bighorn National Forest. The rust fungus also infects alternate hosts of currant or gooseberry plants (*Ribes* spp.) to complete its life cycles. The fungal spores spread by wind from the *Ribes* plants to infect pine needles. After a short infection time, the fungus will develop cankers that girdle and kill branches and eventually stems. Around the edges of these cankers, the fungus produces blisters of spores that travel to infect the *Ribes* plants. While spores from ribes have been shown to travel a great distance and still be viable, we find most pine infections in Wyoming occur in areas where ribes plants grow in close proximity to the trees (Mielke 1943).

White pine blister rust has been very damaging to limber pine stands in Wyoming. Current monitoring studies are being done on the Bighorn National Forest to evaluate disease spread and infection levels. The only control for this disease consists of cutting infected trees for sanitation purposes.

Dwarf Mistletoe diseases

Dwarf mistletoe is a parasitic plant that attacks conifers throughout the western U.S. (Hawksworth and Johnson 1989). The Little Bighorn Analysis Area has two species of

dwarf mistletoe. *Arceuthobium americanum*, which is specific to lodgepole pine, and *A. cyanocarpum* which grows on limber pine.

It spreads to nearby trees by dispersing seeds which land on the needles of lodgepole pines. The seed grows into the tree's xylem and slowly develops an endophytic system along the tree branch to absorb water and nutrients from the tree. In the early stages of infection, these infected branches may appear swollen or cankered.

Three to four years after infection, the dwarf mistletoe will produce male and female aerial shoots. These shoots are small, pale green, and leafless. The male shoots produce staminate flowers which release pollen. The females shoots have pistillate flowers that develop into seeds shortly after pollination. After seed or pollen dispersal, the terminal portion of the shoots wither and fall from the host tree. The residual shoots remain to produce a new seedcrop the next year (Hawksworth and Johnson 1989).

Dwarf mistletoe spreads to nearby trees by discharging its seeds up to 50 feet from the host tree. Sometimes the seeds will reinfect the same tree especially if the seed-bearing shoots are produced in the top of the tree. However, spread usually occurs from overstory to understory trees. Occasionally, the seeds can be spread long distances by wildlife that come into contact with the seeds.

Infected branches produce excessive, abnormal branching in the form of witches brooms. The branches and infected stems may have abnormal swellings and cankers that develop; the cankers can be entry sites for other decay fungi. In time, the stem cankers girdle the tree and cause topkill. Eventually, the parasites kills the trees unless it succumbs to other mortality agents first. Insects, particularly bark beetles, may cause an earlier death by attacking weakened heavily infected trees (Johnson et al. 1979; Tkacz and Schmitz 1986).

Dwarf mistletoe affects forest management in other ways besides causing tree mortality. Tree growth is greatly reduced by dwarf mistletoe infection. Studies have shown that dwarf mistletoe infected trees had less radial increment growth than uninfected trees (Myers et al. 1971). The disease often makes sites appear to be poor quality, but in reality, the dwarf mistletoe is slowing tree growth not site quality. The disease also lowers timber quality, reduces seed production, and make trees more susceptible to root disease and insect attacks. Visual quality is also reduced with increases in spike-tops and witches brooms. Wildfire susceptibility increases in severely infected stands. The witches brooms and the topkilled trees create fuel ladders for low intensity ground fires to climb into the canopy becoming high intensity wildfires.

The disease spreads slowly, about 1-2 feet per year in even aged stands. Uneven-aged stands will have a greater spread and seeds fall from the infected overstory to the understory trees. Selective cutting has perpetuated this disease. Infected trees along visual and wildlife corridors have increased disease spread. Reduced clear cutting and small harvest units (less than 20 acres) have contributed to increased spread from infected forest stand edges.

Fires used to help to sanitize areas of dwarf mistletoe by creating fuel ladders due to the dwarf mistletoe brooms. The brooms allowed low intensity fires to climb into the crowns of the trees and the fire then sanitized the site by killing infected host trees. With fire suppression came increases in the incidence and severity of this disease in forest stands. Today, prescribed fires that destroy most of the stand could be used to clean up heavily dwarf mistletoe infested stands and allow uninfected tree regeneration to colonize the site (Zimmerman et al. 1988).

The dwarf mistletoe infection on the Bighorn National Forest occurs in 36.5 % of the lodgepole pine acreage. Suppression programs could be done on the Bighorn National Forest to reduce the impacts of this disease (Johnson 1986).

Effective controls and suppression for dwarf mistletoe can be handled silviculturally. The parasite requires a living host; when the trees are cut then the parasite dies. The dwarf mistletoe is specific to a tree species; favoring another tree species will reduce the parasite on the site. The mistletoe spreads slowly and clear cuts will prevent its spread into uninfected stands. The dwarf mistletoes have long life cycles; infected seed trees may be used to restock a site if they are removed within about 10 years. The disease is easy to detect and rate which can help in making management decisions for a site. Presuppression surveys can help define areas that need treatment.

Silvicultural treatments can be designed to use natural and artificial barriers such as ridgetops, roads, and creeks to prevent dwarf mistletoe seed dispersal (Dooling and Brown 1976). Wider clear cuts that avoid long, narrow strips so that edge-effect is reduced may prevent dwarf mistletoe spread into new stands (Hawksworth 1958). Shelterwood and seed tree cuts may also be used if the infected overstory can be removed within 10 years. A sanitation-thinning may be used when a stand is lightly infected. This kind of thinning works well if the stand dwarf mistletoe ratings is 1 or 2; all infected overstory and understory trees are felled. Replacing the stand is recommended for heavily infected stands with dwarf mistletoe ratings of 3 or greater (Hawksworth and Johnson, 1989). In Wyoming, dwarf mistletoe also has an elevational limit which is up to 500 feet below the elevation of lodgepole pine. The disease may be absent in the elevational difference and may allow more management alternatives (Dooling and Brown 1976).

There are several benefits for doing dwarf mistletoe suppression. Dwarf mistletoe slows down rotation age and reduces timber quality. Expenses for site preparation, tree planting, and thinnings are worthwhile when dwarf mistletoe spread into healthy stands is prevented. Uninfected stands will be more productive and meet greater timber targets. The stands will be less susceptible to wind damage, fire, and insect/disease activities. Future rotations will be less likely to become infected with dwarf mistletoe disease.

Management decisions for dwarf mistletoe control should be based on individual site conditions. Stand composition, density, disease incidence and severity will all play a role in future management plans. Available stand growth and dwarf mistletoe infection models may help in determining these management plans.

Needlecast diseases

Lophodermella spp. needlecast disease outbreak occurred on lodgepole pine of the Bighorn National Forest in the early 1990's. The needlecast disease was found on over 12,000 acres on the Bighorn National Forest but remained at outbreak levels for only 2 - 3 years.

Currently, the limber pine on the forest may be experiencing a widespread needlecast disease outbreak. Limber pine stands have been noticed to be declining in Wyoming and Montana. In Montana, *Dothistroma septospora* needlecast disease has been identified as a major contributor to this decline (Taylor and Schwandt 1998). It is possible that this disease is also active in the Bighorn National Forest. Investigations into this possibility will be done in the 1999 field season.

Infection by these needlecast fungi occurs in the spring and symptoms of reddish brown needles become apparent in the autumn or following spring. The fungi are usually identified by their small, elliptical, dark fruiting structures formed on the needles. The needles are soon cast from the tree and repeated defoliation over a few years may cause mortality.

Forest management in areas with high needlecast disease problems should focus on favoring apparent resistant tree individuals. Since the needlecast diseases are found on the pines in the Little Bighorn Analysis Area, then other tree species may be favored in these areas (Johnson 1986).

METHODS

Bighorn National Forest managers began an environmental assessment in 1998 to address the impacts of their proposed vegetation management plans. A goal of these plans for the Little Bighorn Analysis Area is to "minimize insect populations and spread of disease". Forest managers asked Forest Health Management to assess the current insect and disease damages in the Little Bighorn Analysis Area for the future Environmental Assessment.

Staff from the Rapid City Service Center conducted a survey of the possible damaging insects and diseases in the area. The survey's emphasis was especially focused on bark beetles of spruce, fir, and pine, root diseases, rust diseases, and dwarf mistletoe diseases.

Chain-wide survey transect lines were traversed to detect and evaluate the insects and disease pathogens of the forested area (Figure 1). Three-person crews surveyed 12.5 miles of transects to detect insect and disease activity by two different methods. First, dying or recently dead trees along the lines were examined for beetle or/and root disease activity. Second, variable-radius plots every 10 chains along the transect lines were used to evaluate dwarf mistletoe and rust diseases.

While traversing the transect lines, any dying or recently dead trees (trees with yellow or red foliage) were examined for beetle or root disease activity. Counts were made of the

various bark beetle attacked-trees along the transects. If root diseases were found, then they were identified and their location was noted during the survey.

Variable-radius plots, used for rust and dwarf mistletoe disease evaluations, were based on a basal area factor "20". These plots were installed every 10 chains along the transect. All trees in the variable-radius plots were evaluated for:

- Species;
- Size Class - seedling, sapling, pole, and sawtimber;
- Health Status - healthy = no defects or injuries, declining = 1 major or 3 minor injuries, dying = 2 or more major injuries, recently dead, long dead;
- Dwarf Mistletoe - the Hawksworth 6-class dwarf mistletoe rating system
- Comandra Blister Rust - a new 5-class rating system was used. This system was similar to the dwarf mistletoe rating system. The crown base to the top of the tree was divided into thirds. Each third was numbered 1-3 from top to bottom. The rating is based on the numbered section containing the lowest stem canker. The rating is doubled if the canker has girdled the stem.

The survey data for the transects was analyzed by counts and averages for the forest stand conditions and the various insects and diseases. Average DBH and basal areas were calculated for each of the survey transects. Bark beetle-killed trees per acre were calculated. Because tree age and elevation by plot was not known, mountain pine beetle risk rating was not possible for stands of lodgepole pine. Therefore, qualitative estimates of risk were made using only average DBH of lodgepole pine and latitude. Counts of healthy and infected lodgepole pine were made, averages of disease ratings were calculated for the infected lodgepole pine. Root disease was found on one site of the transects; white pine blister rust disease was evaluated by using data from a wpbr study plot installed in 1997 in the analysis area.

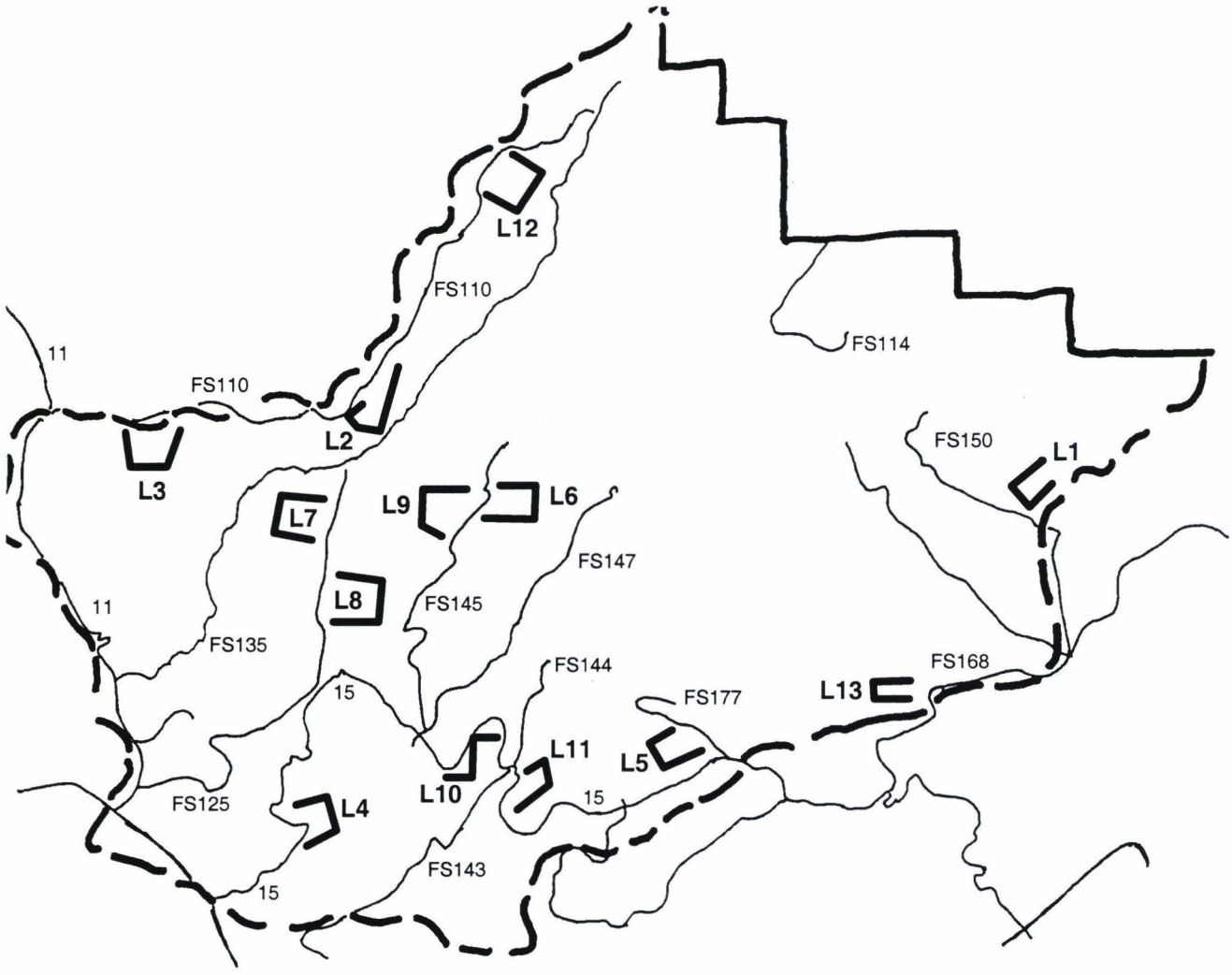

Figure 1. Map of Little Bighorn Analysis Area and cruise lines relative to Forest Service road system.

SURVEY RESULTS AND DISCUSSION

Forest Stand Conditions

For the area studied within the Little Bighorn Analysis area, the forest stands were primarily comprised of spruce-fir habitat and a lesser, but still significant component of lodgepole pine (Table 1). Trees within these stands averaged greater than 12 inches DBH and stand densities averaged 135 square feet BA. The eastern and northeastern portions of the study were not examined, but according to forest RIS data are dominated by Douglas-fir, lodgepole pine, limber pine, and ponderosa pine stands. Minor components of all areas were quaking aspen. Many areas within the analysis area had considerable tracts of forest that had experienced severe blowdown and/or fire within recent history.

Table 1. Forest type and cruise line summaries for the insect and disease survey of the Little Bighorn Analysis Area.

Cruise line	Acres	Basal Area[1]	DBH[2]	%SAF[3]	%ES[4]	%LPP[5]
1	8	95	11.1	70.5	24.1	5.4
2	8	120	11.8	38.3	31.0	12.5
3	8	137.5	12.8	39.5	59.6	0.0
4	10	100	11.7	32.1	23.7	44.1
5	8	112.5	11.6	9.7	31.8	58.5
6	8	132.5	13.7	30.8	44.0	25.2
7	8	170	17.3	39.4	43.3	17.3
8	7	140	16.4	22.6	64.3	13.1
9	8	173	15.4	49.8	50.2	0.0
10	8	138	11.1	21.7	76.7	4.6
11	7	163	12.8	17.2	47.6	35.2
12	8	143	10.9	39.6	3.2	57.3
13	4	135	9.6	77.3	5.0	17.8
Total/Ave.	**100**	**135.3**	**12.8**	**37.6**	**38.8**	**22.1**

[1] Basal area in square feet per acre.
[2] Diameter at breast height in inches.
[3] Percentage of cruise line that was sub-alpine fir.
[4] Percentage of cruise line that was Engelmann spruce.
[5] Percentage of cruise line that was lodgepole pine.

Insects

Bark beetle activity within the analysis area is summarized in Table 2. Most of the damage in the spruce-fir forest type was caused by western balsam bark beetle-disease complex and spruce beetle. Stable populations of western balsam bark beetle were observed based on the number subalpine fir killed in 1997 (2.3 trees per acre) and 1998 (2.3 trees per acre). This level of activity should be considered near outbreak level. Fewer spruce trees were killed per acre by spruce beetle than by western balsam bark beetle. Although the level of spruce beetle activity is at endemic levels, there were some moderately large pockets of spruce mortality within the study. The spruce-fir stands within the Little Bighorn

Analysis area should be considered high risk because of the large diameters, high proportion of spruce-fir, and relatively high stand densities (Table 1).

Mountain pine beetle activity also was comparatively less. Less than 1 tree killed per acre is considered an endemic level. Based on tree diameter, latitude, and approximate elevation data collected from the cruise lines, lodgepole pine stands were moderate to low risk. Average diameter for lodgepole pine trees measured within the study area was 11.8 inches. Obviously, stands consisting predominantly of regeneration will have lower DBH and be of less risk to pine beetle outbreak. Lodgepole pine stands at relatively lower elevations (e.g., <7,500 ft.) are higher risk than stands at high elevation (e.g., >8,500 ft.) for a latitude of $44^{0}5'$ N latitude. In the ponderosa pine stands there were some small pockets of beetle activity already present. Much of the ponderosa pine appeared to be at a stage that would be highly susceptible to beetle attack, with large diameter trees in fairly dense, pure stands of pine.

Douglas-fir in this the study area was not documented; however, based on past activity in the area, there is likely to be a problem in multi-storied stands of Douglas-fir and in Douglas-fir stands affected by blowdown or fire scorch.

Table 2. Summary of trees killed per acre by bark beetles in the Little Bighorn Analysis Area.

Cruise Line	WBBB		SB		MPB		Total	
	1998	Old	1998	Old	1998	Old	1998	Old
1	1.0	2.0	0	0	0	0	1.0	2.0
2	5.1	5.3	0.9	0	0	0	6.0	5.3
3	1.9	2.1	0.1	0	0	0	2.0	2.1
4	0.2	0	0	0	0	0	0.2	0
5	1.5	1.5	0	0	0.1	0	1.6	1.5
6	1.4	2.3	0	0	0	0	1.4	2.3
7	2.4	1.4	0.8	0	0.5	0.3	3.6	1.6
8	3.0	5.0	2.3	0	0.1	0	5.4	5.0
9	3.8	2.9	0.1	0	0	0	3.9	2.9
10	4.5	5.0	1.0	1.1	0	0	5.5	6.1
11	2.9	1.6	0.4	0	0.6	0.1	3.8	1.7
12	1.6	0.5	0	0	0.3	0	1.9	0.5
13	0.8	0.5	0	0	0	0	0.8	0.5
Mean	2.30	2.30	0.43	0.09	0.12	0.03	2.85	2.42

Diseases

Armillaria root disease was found in one area of our transects in the Boyd Ridge area near Leaky mountain. If forest managers need more information about the distribution of this root disease, further survey work will be needed. More root disease survey for Annosus root disease may help forest managers with areas of sub-alpine decline due to root disease.

Of the trees surveyed in the variable radius plots along the transects, 204 were lodgepole pine. Of these lodgepole pine, 40% were infected with either comandra blister rust and/or dwarf mistletoe diseases. Sixteen percent of the lodgepole pines surveyed have both diseases. Twelve percent were infected with only comandra blister rust disease and another 12% were infected with dwarf mistletoe disease only (Figure 2).

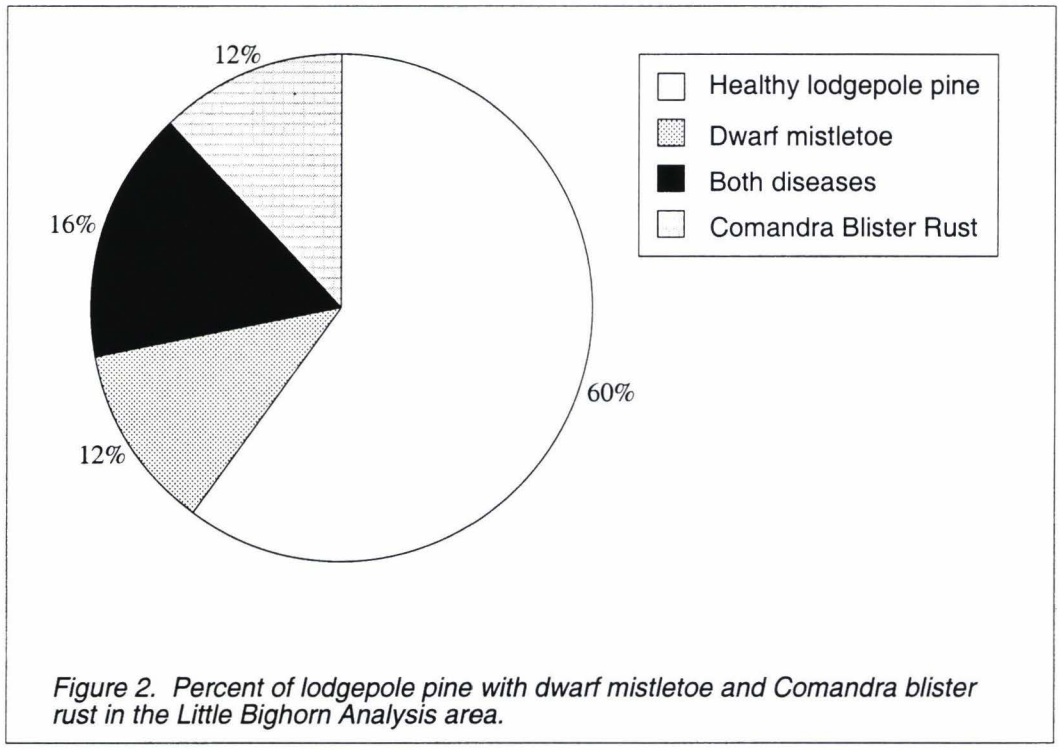

Figure 2. Percent of lodgepole pine with dwarf mistletoe and Comandra blister rust in the Little Bighorn Analysis area.

The comandra blister rust incidence on lodgepole pine in the Little Bighorn Analysis Area is high with 28% of all lodgepole pine trees infected with the rust (Figure 2). An average severity rating was calculated at 3.0. This severity rating indicates that these lodgepole pine trees have girdling cankers in the middle section of their crowns or non-girdling cankers in the lower portions of the crowns. For trees with girdling cankers, this rating indicates that a large portion of the crown is topkilled and the trees are in a serious state of decline. Trees with non-girdling cankers in the lower crown may soon be topkilled as the cankers grow towards the stem and girdles it. These trees are not growing and yet will continue to use valuable site resources for possibly several more decades reducing the vigor of surrounding, competing trees.

White pine blister rust was confirmed on only a few limber pines in the area. However, there was significant branch mortality, which may be caused by the rust, but confirmation of the disease was not possible. While the disease has great potential to decimate limber pine, in this area it appears to be at a low incidence level. Further monitoring of this disease will be done in the Little Bighorn Analysis Area with long-term plot work started in 1997.

The average dwarf mistletoe rating for all the dwarf mistletoe infected trees was 3.3. This rating indicates that the disease is at a medium level of infection on the diseased trees. The disease will continue to progress in these trees, spread to nearby lodgepole pines, and reduce growth and vigor on the site. Some of the trees did have high dwarf mistletoe ratings and will die within a few years. Suppression efforts in some of the more heavily infected stands may be able to reduce the disease and encourage a healthy stand on the site.

Dwarf mistletoe incidence on lodgepole pine for the Bighorn National Forest was reported as 36.5% of acres surveyed (Johnson, 1979). The survey on the Little Bighorn Analysis Area was less with only 16% infection among all trees and 30% infection among all lodgepole pine (Figure 2) . Perhaps this is due to the different methods used for surveying and analysis. This reduced dwarf mistletoe incidence may also be due to a large number of spruce-fir type and limber pine type sites found during the survey. The spread of dwarf mistletoe is gradual and slow, and unless a stand or plot is near infected trees then it will probably not be infected.

Severity ratings for dwarf mistletoe were calculated by averaging all infected trees of the variable radius plots. While clear cuts or stand-replacing fires are the recommended treatments for stands with high dwarf mistletoe ratings (DMR>3.0), stands with lower ratings may be able to use a variety of selective cuts.

RECOMMENDATIONS

The following are our recommendations for management of forested areas within the Little Bighorn Analysis Area for increasing the overall health of the forest. Management should try and simulate the natural disturbance processes that have shaped this area over time while providing for meeting the desired objectives of this area. The most common disturbance agents in this area include fire, insects and diseases, and windthrow events.

1. Spruce/fir - Use of stand replacing fire/small patchcuts

The spruce/fir type in much of this area seems to be mature to overmature and needs to be regenerated. There is a considerable amount of "fir decline" throughout the Little Bighorn Analysis Area, and although the causes are not specifically known, at least a part of the problem could be related to an increase in overmature fir stands. The use of stand replacing fires in spruce/fir should return the area to an earlier successional stage, perhaps in some places even regenerating additional lodgepole pine stands. Stand replacing fires could be used to take out the declining stands.

The use of low intensity fires to remove understory vegetation is not recommended. Fires would have to be executed cautiously, as fire scorched spruce trees can be highly attractive to spruce beetles, leading to a buildup in population and beetles killing remaining green trees. Many of the spruce/fir stands have high basal areas that largely consist of large

diameter spruce trees. These conditions are highly susceptible to sustaining an outbreak of spruce beetle should one get started.

The use of small patch clearcuts should be considered in much of the spruce/fir type. This would create openings to regenerate the stands and also provide fire breaks in the landscape that could be used in following stand replacing burns.

A major concern that would need to be addressed in any manipulation of spruce/fir stands is the problem of windthrow. This area seems to have frequent wind events that end in some levels of windthrow, particularly in the spruce/fir type. Windthrown trees can be used by spruce beetle to buildup and then infest standing, green trees. Any treatment, either fire or patchcuts, where the desired condition was to leave much of the surrounding overstory, would have to consider the possibility of windthrow.

2. Douglas-fir type - Use of low intensity ground fires/thinning from below.

In the stands predominated by Douglas-fir, the use of low intensity ground fires can help maintain them. Without disturbance in these areas, they become multi-storied. The understory, typically of Douglas-fir, provides very good habitat for spruce budworm to build up and sustain outbreaks. Use of fire or thinning from below can remove this lower level, making these areas much less suitable for budworm.

The use of fire should be done cautiously if maintenance of the overstory is desired. The Douglas-fir beetle can be attracted to trees that have been fire scorched, but not killed. The beetle can build up in these scorched trees and then spill out and attack nearby green trees. It can lead to impressive outbreaks and a high level of mortality in larger overstory trees. This has been the scenario that has happened on the Shoshone National Forest over the last 10 years following the Yellowstone fires; Douglas-fir beetle built up in scorched trees and proceeded to move out into standing green trees. In some of these areas, it may be best to thin from below prior to introducing fire to make sure that the fire intensity remains low.

3. Lodgepole pine and Limber pine - Use of stand replacing fire/thinning/overstory removal.

The tactic to use in lodgepole pine and limber pine stands is largely going to be dependent on the current conditions in a given stand. In many of these pine stands that are heavily infected with dwarf mistletoe or rust disease, the use of high intensity, stand replacing fires is appropriate. Stands that are heavily infected with mistletoe have historically been prone to these high intensity fires as a method of sanitizing the stand and regenerating a new stand. Less is known about the relationship between comandra rust and fire, but many of these stands have become stagnant and a stand replacing fire may be the most cost efficient way to create healthier stands. Stand replacing fires will also reduce the amount of encroachment from spruce/fir types into areas of pine.

In lodgepole pine stands where past management has occurred, it seemed that the incidence of mistletoe and comandra was much lower than in areas where there had been no management. Our recommendation for areas where past management has occurred is to use timber harvest, in the form of overstory removal, clearcutting or thinning, to maintain these stands in good condition. In areas where much of the overstory has been removed and there is an acceptable level of regeneration, overstory removals should be implemented to lower the chances of spreading mistletoe. In the younger stands, where there are low levels of mistletoe or comandra, precommercial thinning that removes any currently infected trees is advised. In stands that are heavily infected throughout, clearcutting could be substituted for stand replacing fires if feasible.

Overall, it appears that most of the area is in a climatic zone that makes it a low to moderate threat to starting and sustaining a large scale mountain pine beetle outbreak. However, there was evidence that the beetle had been active in this area in the past and had caused a relatively large amount of lodgepole pine mortality, indicating that this area is susceptible to considerable levels of beetle damage. Beetle susceptibility throughout the area can be decreased greatly by lowering the average diameter and tree age of lodgepole pine. Based on this assumption, any activities used to lower dwarf mistletoe or rust diseases would also lower susceptibility to mountain pine beetle.

4. Ponderosa pine type - Use of low intensity ground fires.

In the ponderosa pine area, Douglas-fir is encroaching and becoming a larger part of the stand. This will continue to occur if nothing is done. In this area, the use of low intensity ground fires, to kill some of the Douglas-fir component would help reverse the trend and increase the amount of ponderosa pine. Openings in the pine are going to be created by mountain pine beetle, there is already some minor beetle activity occurring at this time. Beetle activity will likely continue in this area, how much is eventually killed is hard to say, but most of the area seems to be highly susceptible to the beetle. If beetle activity increases to a point where overstory trees are becoming scarce, removal of infested trees in a sanitation activity may be appropriate.

5. Aspen - Clearcut/burn

Aspen is presently a relatively minor component in this area. In spots where it is found and its desirable to expand its range, clearcutting of current aspen stands and surrounding vegetation followed by burning may help stimulate increased aspen suckering. Increasing the amount of new aspen created from seed is more difficult. If stand replacing fires are used in other areas, this may create some habitat that is suitable for aspen regeneration via seed.

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